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ORIGINAL PAPER

Phytosociology, structure and dynamics of *Pinus roxburghii* associations from Northern Pakistan

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Abstract: We investigated the phytosociology, structure and dynamics of *Pinus roxburghii* in 40 stands in northern areas of Pakistan by using cluster analysis (Ward's agglomerative clustering) and ordination (Non-metric Multidimensional Scaling). Cluster analysis revealed three major groups associated with specific environmental characteristics: (1) *P. roxburghii* (2) *Pinus-Quercus baloot* and (3) *Pinus-Olea ferruginea* community types. NMS-ordination showed the major gradient as an amalgam of elevation (r^2 = 0.441, p <0.01) and slope (r^2 = 0.391, p <0.05) as the two topographic factors correlated with species distribution. The first ordination axis also showed positive correlation with soil variables like pH and electrical conductivity, suggesting that soil chemistry was related to topographic characteristics and probably acted as a secondary gradient. We also examined size class distributions, age structures and growth rates of the three communities in order to describe community development and dynamics. Total tree density was 14700 plants/ha, with *P. roxburghii* having a relative density of 82% to 100%. Density of juvenile and total density and basal area of the subordinate tree species were low. The low density of trees in the smallest diameter size-class suggested that the recruitment of small *P. roxburghii* plants into the adult population may be lower than the required replacement rate for the stands. Pooled size-class distributions for the species showed a multimodal pattern with some regeneration gaps. Browsing, heavy logging and other anthropogenic activities were the overriding factors responsible for the poor recruitment of *P. roxburghii*. We concluded from the age structure that the forests were characterized by the dominance of young trees. Growth rate analysis revealed that *P. roxburghii* was the fastest growing species among the conifers species in Pakistan. In view of its relatively fast growth and longevity, *P. roxburghii* seems to be a suitable choice for short-term cultural practices in order to enhance wood production in lesser Himalaya and Hindukush ranges of Pakistan.

Keywords: phytosociology, structure, dynamics, multivariate techniques, dendrochronology, Himalayan range

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Introduction

In Pakistan, about 4.8% of the total area is forested which is very low in comparison to 23−70% in other countries of the world (Ahmed et al. 2010; Khan 2012). One-third of the forested area in Pakistan is covered by productive forests and the remaining two-thirds are categorized as protected forests (Sethi 2001). The sub-tropical pine forests located in the lesser Himalayan and Hindukush range of Pakistan are dominated by broad-leaved and coniferous tree species have significant contribution to productive forest types. To date, eight conifer tree species have been reported (Nasir and Ali 1972) of which two species *i.e*. *P. brutia* and *P. halepensis* are not native to Pakistan. Among the native tree species *Pinus roxburghii* (Chir pine) is considered to be an important species (Gupta and Dass 2007) occurring at elevations from 900 to 1800 m above sea level (Siddiqui et al. 2009). In Pakistan this species is distributed in the lower parts of Khyber Pakhtunkhwa, Azad Jammu and Kashmir in sub-tropical dry and moist temperate areas (Ahmed et al. 2006), while it is also planted in certain areas of Punjab along roadsides and gardens. It is the only pine in the country of the northern forests with a small overlap with *Pinus wallichiana* (Kail) at the upper elevation limit (Saddozai 1995). *P. roxburghii* has a wide ecological amplitude and considerable economic importance, providing large stretches of grazing lands due to its typically well-developed grass layer (Wahab 2011) and valuable timber-wood and resin. Hence most of the population in its zone of occurrence depends on these

forests for various purposes (Gupta and Dass 2007). The ecological role of *P. roxburghii* forests is also important in terms of watershed, microclimate, anti-erosion, sanitary-hygienic, recreation and conservation functions (Malabadi and Nataraja 2006; Ravindra et al. 2007).

In addition to its ethno-botanical importance, *P. roxburghii* is also used as charcoal, dye, herbicide, ink, lighting, resin and wood, while the importance of these forests as a source of many other bio-resources including mushrooms, medicinally important herbs, shrubs and game can also not be ignored (Ghildiyal et al. 2010). Owing to the economic importance of *P. roxburghii*, its intensive usage and direct devastation have gradually led to shrinkage of the forested area and degradation of this ecologically and commercially important species (Nafeesa et al. 2007; Miehe et al. 2009). Most of these stands are isolated and have reduced wood properties, low productivity and decreased farming and resource significance. The large scale destruction of forests in many sectors has resulted in several environmental problems (Singh 1985; Ives and Messerli 1989) that have caused changes in vegetation structure, diversity and composition (Gaur 1982). Knowledge of the current floristic composition and structural attributes is useful in understanding the prevailing status of commercially and ecologically important species because this underpins resource description, land-use planning and conservation management (Singh 1976; Kumar et al. 2004).

The structural and functional parameters of *P. roxburghii* associations in Pakistan were reported by Ahmed et al. (2006). Information related to these communities was also published by other workers (e.g. Ashraf 1995; Ajaib and Khan 2004; Ajaib et al. 2004; Malik et al. 2007; Nafeesa et al. 2007; Siddiqui et al. 2009; Shaheen et al. 2011; Wahab 2011). Some dendroecological and dendrochronological studies have been reported by Ahmed et al. (2009). However, little is known of the phytosociology, structure and dynamics of the species. Therefore, the present study was designed with the following specific objectives: (1) quantify the relationship of species composition and stand structure attributes of *P. roxburghii* forests with relation to major environmental variables in northern Pakistan, (2) elucidate growth and development patterns of the forest species with relation to site variables, (3) compare the pine forest in the study area with other forests on national and regional levels. Results described here may be used as reference conditions for similarly situated forests on the lesser Himalaya and Hindukush range that are being managed for old growth characteristics (*i.e.* growth rate, age, diameter and vertical structure).

Materials and methods

Study area and climate

The northern areas of Pakistan cover about 72500 km^2 spanning from 34° to 37° N and 71° to 74° E (Ahmed et al. 2011). There are three well-known ranges of mountains *i.e.* the great Himalayas (average elevation 4000 m), which stretch for about 2500 km from east to west and border the Hindukush range (5000 m) to the northwest and Karakorum to the north (Sethi 2001). Geographically, the area is linked with China through the famous Silk Road which is roughly 4700 m above sea level and reported to be the highest sealed highway in the world (Brian 1991). The area adjoins the disputed territory of Kashmir to the east and Afghanistan to the west (Sheikh 1993). The lesser Himalaya is of middle elevation (1800–4500 m), represented by the Pir Panjal range, and increases in elevation from south to north. The Hindukush range has a number of passes *i.e.* Shandur pass (3700 m) that connect Gilgit-Baltistan and Chitral (Geoffrey1984), Shangla pass (3000 m) links Swat valley to the upper parts of the Indus valley while the Lowari pass (3118 m) connects Chitral to Dir, Swat and Peshawar (Manfred et al. 1986; 2000).

Major portions of these mountains are generally bare of vegetation though rich forests are found in some areas (Champion et al. 1965). However, *P. roxburghii* is completely absent in the Karakorum range (personal observations). These mountain ranges have a variety of micro-climates typically of highland type (Fowler and Archer 2006) and consequently support a variety of vegetation types (Shaheen et al. 2011). Winters are long, cold and snowy while summers are short and mild. Rainfall is highest in highland zones and usually associated with elevation (Hussain et al. 2010), while some areas like north-west Gilgit and Chitral experience low rainfall as they are rain shadow areas beyond the reach of the monsoon (Khan et al. 2013).

Field methods

Vegetation survey and soil analysis

After the general reconnaissance of the study area, 40 stands dominated by *P. roxburghii* were sampled throughout their natural limits by Point Centered Quarter (PCQ) method (Cottam and Curtis 1956). The sampled forest stands were located both in Hindukush and Himalayan ranges of Pakistan, 2–3 ha in total area, and showed no sign of recent major disturbances. Understorey vegetation including herbs, shrubs, seedlings and saplings was also sampled in 3 m × 3 m quadrats following Ahmed and Shaukat (2012). Twenty-five PCQ points and quadrats were sampled at regular intervals of 20 m in each stand as suggested by Ogden and Powell (1979). Prior to collection of the vegetation data, information was recorded including slope angle (Sunto clinometer), aspect (compass), elevation (altimeter), geographical coordinates (GPS) and the presence of disturbances or human interference. Diameter of all trees (DBH $\geq$ 10 cm; height 1.3 m above ground) and height of saplings (DBH $\leq$ 5 cm) were measured following Ogden and Ahmed (1989). Seedlings (height less than 30 cm) were counted and all recorded species were preserved and identified by reference to literature in Pakistan (Nasir and Ali 1972). Soil samples were collected to a depth of 25 cm using a soil auger at three different locations within a stand and samples were pooled to obtain a composite soil sample. The composite soil samples (CSS) from each stand were subjected to physicochemical analysis following the procedures described by Sparks (1996) and Carter and Gregorich (2008). Soils were sieved through a 2-mm sieve in order to separate pebbles and gravel. Water holding capacity was determined in accordance

with the measurements of Keen (1931) and Carter and Gregorich (2008). Soil organic matter (%) was quantified by loss on ignition at 500ºC. Soil pH was measured in a 1:5 soil: distilled water paste. Major cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) were quantified by an atomic absorption spectrophotometer (Pie-Unicam) after extracting in 0.5 M ammonium acetate. Total soil nitrogen was estimated by the Kjeldahl method (Carter and Gregorich 2008).

Tree-ring width data

Dendrochronology was studied following the general methodology described by Fritts (1976) and Speer (2010). The tree samples in the form of cores were taken using a Swedish increment borer from healthy and sound trees that were also free from severe competition in accordance with the practice of Cook and Kairiukstis (1990). Attempt was made to extract two core radii from each living tree at breast height above the ground, parallel to the slope contour as suggested by Fritts and Wang (1986). The extracted samples were kept in plastic straws with both ends sealed for safety and were labeled with the relevant information (Huang and Zhang 2007). The core samples were dried at room temperature and mounted in a wood skeleton using wood glue following Heinrich (2004). The surfaces of the core samples were smoothed using progressively fine grades of sandpaper following Bowers (1964) and Pilcher (1990).

Laboratory methods

Data analysis

Importance value and absolute values (density/ha and basal area m^2/ha) were computed following Curtis & McIntosh (1950) and Mueller-Dombois and Ellenberg (1974). Densities of herbs, shrubs, seedlings and saplings were calculated on per ha basis. For effective analysis of the vegetation and related environmental variables, both classification and ordination techniques were employed. The input data matrix of tree vegetation of 40 forest stands based on importance value was developed and subjected to cluster analysis and ordination using PC-ORD version 5.10 (McCune and Grace 2002). We applied Ward's agglomerative clustering technique (Orloci and Kenkel 1985) for numerical classification of tree species and the results were presented in a dendrogram. No species was excluded as an outlier from the analysis due to the low number of species.

Non-metric multidimensional scaling (NMS) was chosen as the ordination method to investigate the underlying trends in vegetation distribution patterns of the tree species and to correlate the compositional patterns with the set of environmental variables. NMS ordination is often preferred over other popular methods because of its non-linear non-parametric basis, which provides effective ordination of vegetation data where species distributions usually follow non-linear (often Gaussian distribution) patterns (Shaukat 1989; Enright et al. 2005). This ordination method avoids the assumption of linear relationships among variables and the use of rank distances tends to linearize the relationship between distances measured in environmental space. This relieves the "zero-truncation problem" that plagues all ordinations of heterogeneous community data sets (Minchin 1987; McCune and Grace 2002). It allows the use of any distance measure or relativization (MuCune and Mefford 2005). Enright et al. (2005) suggested the use and selection of 1, 2 and 3 dimensions for best solution of interpretation, in terms of trade-off between complexity associated with increased dimensionality and reduction of stress function. We selected the best solution for each dimensionality by choosing the option of the lowest stress value (Timilsina et al. 2007) along with the initial configuration of correspondence analysis (Shaukat 1989). The relationships between environmental variables and NMS ordination of stands were examined by superimposing and contouring the stand data on the ordination configuration. Variables used for NMS were topographic, soil and vegetation variables. The topographic variables were elevation and slope, while soil variables included organic matter (OM %), pH, Carbon (%), Nitrogen (%) Magnesium (%), Sodium (%) Potassium (%) and total dissolved salts. Statistical analyses (ANOVA, Pearson product moment correlation and regression analysis) were performed using SPSS Ver. 14 and Sigma Plot while the group mean vectors of environmental variables were tested by the multivariate statistic "Hoteling's T^2" using the program HOTELLING developed in C^{++}.

Size class distribution

The diameter of *P. roxburghii* was used to construct size-class distributions and associated tree species were not included. Measurements for *P. roxburghii* trees from all 40 stands were pooled following Ahmed et al. (2011) into three groups because of low density. The pooled data were divided into a series of classes, *i.e.* 10−19.9 cm, 20−29.9 cm. For multi-stemmed trees, a diameter was assigned that was equivalent to a hypothetical single stem with a cross-sectional area equal to the sum of all the cross-sectional areas of the individual stems (Russell and Fowler 1999; Ryniker et al. 2006). Juveniles of *P. roxburghii* less than 150 cm in height or less than 3 cm in circumference were excluded from size class structure.

Tree-ring data processing

All cores were not included in the age and growth rate analysis due to missing portions caused by stem-rot in the center of some trees: only those cores crossing the center of the trunk were used in the analysis. Individual cores were examined under a variable power binocular microscope for visual cross-dating (Strokes and Smiley 1968). The age and growth rates of the core samples were calculated following Roza (2004) and Lv and Zhang (2012). In cases where cores did not pass through the center or pith of the tree, we followed Ogden (1980) to calculate the number of missing rings and add these to the total age of the tree. Three cross-sections were taken at ground level of saplings in each stand and the rings on these sections were counted. It was assumed that the average height and growth rate shown by these saplings could be used to approximate the time required for the tree to reach the height at which cores could be taken (Ogden 1981; Ahmed et al. 2009). These years were added to the age of each core to obtain the total age of the tree. The length of the cores was divided by the number of rings present in the core and the average growth rate in years per centimeter was calculated. Linear regression

was computed for each site to establish the relationships between age, growth rate and tree diameter. For better age estimation, the average age of two cores of the same tree were employed.

Results

Forest structure

Ward's agglomerative cluster analysis resulted in three major groups with 75% of the information in the abundance of species retained (Fig. 1). The percent chaining in the cluster analysis was 10.44%, indicating the effectiveness of cluster analysis. Three major groups/associations were identified as described below.

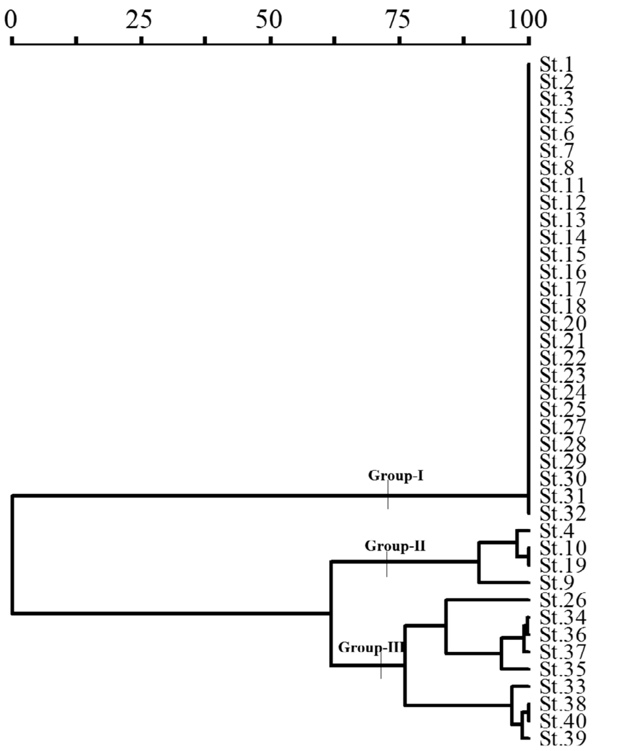

Fig. 1: Dendrogram showing the different associations identified by the hierarchical agglomerative cluster analysis based on importance value of trees.

P. roxburghii association

Group I, the *P. roxburghii* association, was represented by 27 sites/stands (Fig. 1). Among these sites *P. roxburghii* occurred as a pure community (100% IVI) and the trees were distributed exclusively at dry and moist sites of the subtropical areas of the Hindukush and Himalayan ranges (Table 1). The range of density ha^{-1} in this pure association was 41−1490 trees/ha with a mean of 398±69 trees/ha (Table 2). The total density in this group was 14700 trees/ha. The mean density of seedlings (234±51 individuals/ha) was higher than that of saplings (166±34 individuals/ha) in this group.

Table 1: Mean importance value in the three groups of tree vegetation derived from Ward's cluster analysis.

Tree species	Group 1	Group 2	Group 3
	Mean±SE	Mean±SE	Mean±SE
P. roxburghii	100±00	62±2.8	62.1±2.6
Q. baloot	×	32±4.9	0.314±0.2
Q. dilitata	×	5±4.91	2.84±1.0
A. modesta	×	×	4.1±1.3
B. papyriffera	×	×	1.7±0.43
C. serrate	×	×	0.5±0.6
M. buxifolia	×	×	8.5±4.9
O. ferruginea	×	×	17.5±3.6
P. granatum	×	×	2±1.0
F. palmata	×	×	0.5±0.3

Table 2: Mean density/ha in the three groups derived from Ward's cluster analysis.

Tree species	Group 1	Group 2	Group 3
	Mean±SE	Mean±SE	Mean±SE
P. roxburghii	398±69	85±9.25	386±78.99
Q. baloot	×	24±10.96	13±2.5
Q. dilitata	×	16±5.89	3.5±1.0
A. modesta	×	×	16±3.9
B. papyriffera	×	×	8±00
C. serrate	×	×	2±00
M. buxifolia	×	×	28±12.5
O. ferruginea	×	×	53±15.7
P. granatum	×	×	5±1.8
F. palmata	×	×	1±00

Table 3: Mean basal area m^2/ha of the three groups derived from Ward's cluster analysis.

Tree species	Group 1	Group 2	Group 3
	Mean±SE	Mean±SE	Mean±SE
P. roxburghii	129±33	57±16.09	125±32
Q. baloot	×	10±4.50	4±1.6
Q. dilitata	×	6±1.99	1.4±0.8
A. modesta	×	×	3.1±0.9
B. papyriffera	×	×	0.2±00
C. serrate	×	×	0.02±00
M. buxifolia	×	×	6.±0.85
O. ferruginea	×	×	14±2.88
P. granatum	×	×	2±0.37
F. palmata	×	×	0.32±00

Note: × is absence of species in different groups.

Basal area of the dominant species ranged from 9−898.9 m^2/ha with a mean of 129±33 m^2/ha (Table 3), while the total value for basal area was 3468.99 m^2/ha. A number of herbs and shrubs were recorded apart from the seedlings and saplings of the overstory tree species. Among these *Dodonea viscosa*, *Indigofera*

gerardiana, *Buddleja crispa*, *Isodon rugosus*, *Maytenus royleanus*, *Heteropogon contortus*, *Viola biflora* and *Micromeria biflora* were frequent species with frequency ranging from 10−100% in this group.

P. roxburghii–*Quercus baloot* association

Group II, the *P. roxburghii*–*Q. baloot* association, was recorded at three sites. Two sites in this association were from the sub-tropical moist temperate area and one site represented the dry temperate area. Among the tree species *P. roxburghii* was dominant with 62±2.8% importance value followed by *Q. baloot* (IV=32±4.9%) and *Quercus dilatata* (IV=5±4.91%) (Table 1). Mean tree density of the leading species was 85±9.25 trees/ha (range 66−98 trees/ha), whereas the total trees numbered 253 trees/ha, less than for groups I and III (Table 2). The basal area ranged from 38 to 89 m^2/ha with a mean of 57±16.09 m^2/ha. The overall basal area of *P. roxburghii* was 171 m^2/ha. The density of *Q. baloot* ranged from 3 to 40 trees/ha (of a total of 72 trees/ha of all species) with an average of 24±10.9 trees/ha. *Q. baloot* basal area ranged from 0.87 to 15.5 m^2/ha (of the total for all species of 29.23 m^2/ha) with a mean value of 10±4.50 m^2/ha. *Q. dilatata* was a sub-ordinate species at a density of 16±5.89 trees/ha with an average basal area of 6±1.99 m^2/ha (Table 3). Saplings of the dominant tree were more numerous as compared to the total saplings of the other species (12−33 individual ha^{-1}). *Dodonea viscosa*, *Berberis lycium*, *Mallotus philippensis*, *Myrtus communis*, *Viola biflora* and *Fragaria nubicola* were dominant understory herbs and shrubs at 20 to 70% frequency.

P. roxburghii–*Olea ferruginea* association

Group III, the *P. roxburghii*–*Olea ferruginea* association, was found at 10 sampled locations. These were located in the dry temperate area though a few sites were near moist temperate sites. Ten tree species were recorded in the group in which *P. roxburghii* was highly dominant (IV=62.1±2.6%) followed by broad leaved *O. ferruginea* (IV=17.5±3.6%) and *Monotheca buxifolia* (IV=8.5±4.9%) (Table 1). Three species, *Acacia modesta*, *Quercus dilatata* and *Punica granatum*, were comparatively abundant, whereas the remaining species had importance values of less than 1%. The overall density and basal area of trees in this group was 2521 individuals/ha and 1400 m^2/ha, respectively. *P. roxburghii* shared a total density of 1251 trees/ha (average=386±78.99 tree/ha) and a total basal area of 435.77 m^2/ha (average=125±32 m^2/ha). Among the broad leaved species, *O. ferruginea* had the highest density (average=53±15.7 trees/ha) and basal area (average=14±2.88 m^2/ha) followed by *M. buxifolia* at an average density of 28±12.5 trees/ha and basal area of 6±0.85 m^2/ha. Other species had average densities less than 8 trees/ha with a small fraction of the basal area (Tables 3 and 4). Group III, however, had highest species richness followed by Group I. In addition, density values for juveniles were higher for the dominant species followed by *Olea ferruginea* and *M. buxifolia*. The understory was dominated by *D. viscosa* at 100% frequency followed by *Teucrium stocksianum* (50%), *Ajuga parviflora* (50%), *Indigofera gerardiana* (30%) and *Otostegia limbata* at 20% frequency. *Phagnalon niveum*, *Filago hurdwarica*, *Limonium cabulicum* and *Periploca aphylla* were the sparsely distributed species.

Table 4: Means of environmental variables for the groups derived from Ward's cluster analysis.

Factors	Group 1	Group 2	Group 3
	Mean±SE	Mean±SE	Mean±SE
Elevation	1322±43	1137±75	1734±481
Slope	31±2.1	28±3.8	19±1.0
pH	5.2±0.08	6±0.44	6.3±0.17
WHC %	56±1.2	48±1.0	53±1.16
Salinity	0.15±0.01	0.30±0.08	0.26±0.03
Cond.	230±22	237±22	307±65
TDS	167±17	120±11	265±34
OM %	8.3±0.39	6.8±0.5	7.7±0.43
Ca %	0.40±0.06	0.37±0.15	0.45±0.09
Mg %	0.45±0.02	0.61±0.02	0.54±0.04
Na %	0.77±0.09	0.61±0.14	0.55±0.03
K %	1.6±0.11	1.9±0.23	1.6±0.20
N %	0.19±0.06	0.14±0.04	0.17±0.03

Note: WHC= water holding capacity %, OM= organic matter, TDS= total dissolved solids

Environmental characteristics of the groups

The environmental variables recorded for the three groups showed marked differentiation (Table 3). Group I was set apart with low elevation, low slope angle, low pH, and high water holding capacity (WHC %), organic matter (OM %), total dissolved salts (TDS), sodium (Na %), magnesium (Mg^{+2}), potassium (K %) and nitrogen (N %). Calcium (Ca^{+2}) concentrations were higher than at Group II sites and lower than at Group III sites. Group II was characterized by low elevation, water holding capacity, organic matter, salinity, conductivity, and Nitrogen. Conversely, slope gradient, pH and Mg^{+2} content were higher in this group. Finally, Group III was characterized by high elevation, low slope angle and high pH and Ca^{+2} content. The salient feature of this group also included high conductivity, salinity and K^+ content in comparison with the other groups.

Statistical analysis

The groups derived from Ward's clustering technique with their corresponding environmental variables were analyzed by univariate analysis of variance (ANOVA). Elevation and slope were significantly correlated (F =7.5; p <0.01). The edaphic variables including soil pH, water holding capacity, salinity and conductivity were non-significant. Soil organic matter and nutrients (Ca, Mg, Na, K and total N) showed non-significant differences between group means.

The multivariate assessments of ecological parameters of the groups were also compared based on mean vectors by the application of Hotelling's T^2 test. The topographic, edaphic and soil nutrients were compared between pairs of groups with respect to

the first set of variables (topographic). The comparison between group I and II yield a significant difference (F =3.4, df_1 =27, df_2 =10, p <0.05). However, the mean vector for groups I and III were not significant (F =1.43, df_1 = 27, df_2 =3 ns), while groups II and III had significantly different mean vectors (F =5.8, df_1 =10, df_2 =3 p <0.01). With respect to the edaphic variables, the comparison of groups I and II showed non-significant difference (F =0.9, df_1 =27, df_2 =10 ns). Similarly, groups I and III were similar (F =0.462, df_1 =27, df_2 =3 ns), as were groups II and III (F =0.487, df_1=10, df_2 =3 ns). Mean vectors for nutrients in groups I and II, I and III and II and III did not differ significantly.

Forest–environment relationships (Ordination)

The 2-D NMS ordination of tree vegetation data (stands ordination) is shown in Fig. 2. The results of stand data yielded a two dimensional configuration with a comparatively high (20%) stress value. The groups/community types derived from Ward's agglomerative clustering strategy were superimposed and were clearly separated in the ordination space. The results revealed that axis 1 alienated the *P. roxburghii* pure community from the *P. roxburghii* - *Q. baloot* and *P. roxburghii* - *O. ferruginea* community types. *P. roxburghii* pure community type was distinguished from the other two groups on axis 2.

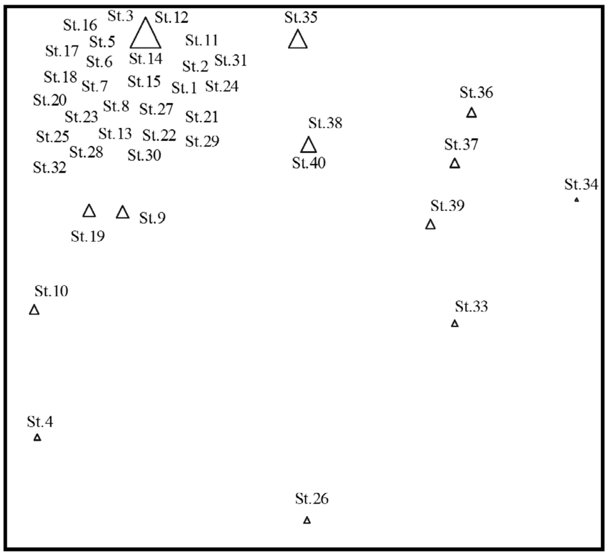

Fig. 2: NMS ordination of tree vegetation (stands) representing three major groups derived from cluster analysis were superimposed on the 2-D ordination space.

The correlation of environmental variables and the NMS ordination axes suggested a strong relationship between elevation (r^2 =0.441, p <0.01) and slope (r^2 =0.391, p <0.05) along the first ordination axis. Soil pH was also significantly correlated (r^2 =0.423, p <0.01) with ordination axis 1 (Table 5). Salinity, conductivity and total dissolved salts were also significantly correlated with ordination axes 1 and 2 (p <0.05). Among the other measured variables, water holding capacity (WHC), organic matter (OM) and available Ca^{++}, $^{+2}$, Mg^{+2} , K^+, Na^+ and N^+ did not yield significant relationships with any of the ordination axes (Table 5). The environmental parameters were also tested using one-way ANOVA and indicated statistically significant differences between the groups in terms of topographical variables.

Table 5: Pearson's product moment correlation coefficients between the ordination axes and the environmental variables examined.

No.	Variables	Axis 1	Prob. Level	Axis 2	Prob. Level
1	Elevation	0.441**	p<0.01	0.181	Ns
2	Slope	0.391*	p<0.05	0.191	Ns
3	pH	0.423**	p<0.01	0.042	Ns
4	WHC %	0.139	Ns	0.042	Ns
5	Salinity	0.315*	p<0.05	0.334*	p<0.05
6	Cond.	0.326*	p<0.05	0.358*	p<0.05
7	TDS	0.322*	p<0.05	0.337*	p<0.05
8	OM %	0.302*	p<0.05	0.211	Ns
9	Ca	0.081	Ns	0.025	Ns
10	Mg	0.064	Ns	0.151	Ns
11	Na	0.057	Ns	0.118	Ns
12	K	0.09	Ns	0.056	Ns
13	N	0.083	Ns	0.134	Ns

Significance levels: *: p <0.05; **: p <0.01 and Ns: Non-significant

Size class structure

Size class structure based on diameter of trees across the 40 stands was pooled into three groups (Fig. 3). The pooled diameter distribution showed an uneven size structure, with monotonically decreasing density with increasing tree size up to the largest DBH class in group I, which comprised a secondary peak in density. The peak in the largest DBH class resulted in part from inclusion in the class of all trees greater than 40 cm. *P. roxburghii* was present in all DBH classes but well represented in small and medium DBH size classes. *M. buxifolia* was absent from the lowest size class, but was present in other DBH classes at low numbers. The most abundant species in the 10–20 cm DBH class was *O. ferruginea* (47%) followed by *A. modesta* and *Q. baloot*. *P. granatum* were more abundant in < 30 cm DBH classes and rare in classes above 30 cm in all forest stands. These species exhibited an unstable population size structure.

Size class distribution of group II was completely different than for groups I and III. Group II showed a typically uneven pattern of DBH size classes with some regeneration gaps within the larger size classes (Fig. 3b). In this group, *P. roxburghii* represented only 33% of trees in the small size classes while in the medium size classes the density ha^{-1} of trees was higher (50%) than in the small and large size classes. Generally, the number of trees was negligible and regeneration gaps were a prominent feature of this group, particularly in the larger size classes. The size frequency distribution in group III (Fig. 3c) revealed a pattern almost comparable with that of group I. In this group the tree ha^{-1} in smaller and medium size classes was 47% and 26%, respectively. However, nearly 14% of *P. roxburghii* were in large and 12% in giant size classes.

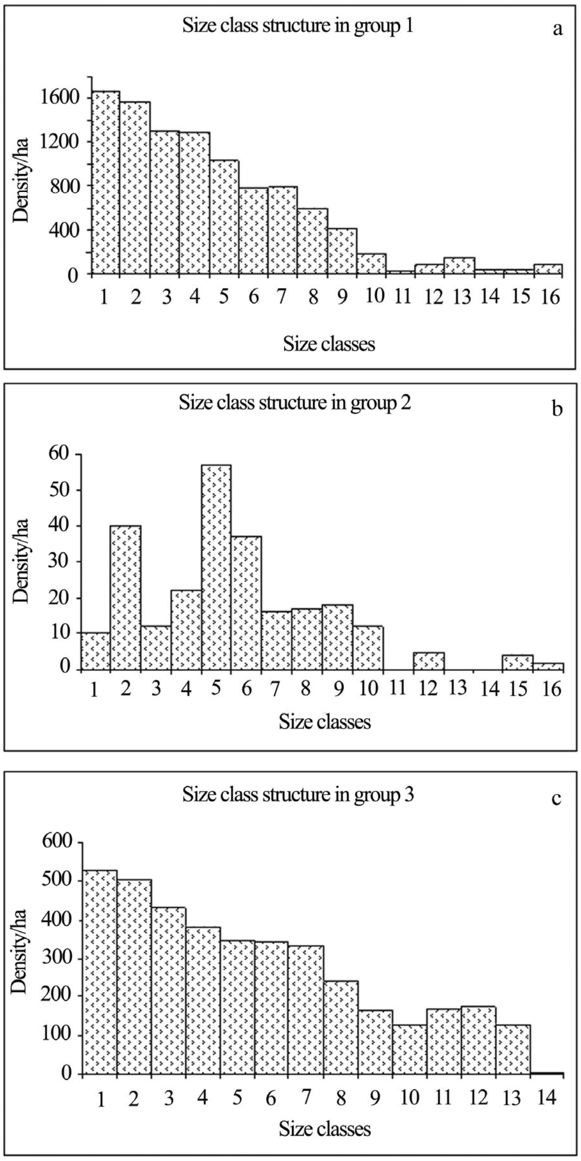

Fig. 3a, b and c: Pooled size class structure of *Pinus roxburghii* based on groups obtained from Ward's cluster analysis of 40 stands. Diameter classes are 10−19.9, 20−29.9, 30−39.9 cm and so on.

Age and growth rates

The diameter of *P. roxburghii* trees in group I ranged from 12−155 cm (Mean ± SE= 57±2.9) while the age ranged from 20−360 years (115±6.8, n=125). Age was positively correlated with diameter (r^2 = 0.7597, p < 0.001). Annual increment was estimated to range from 0.78−5.2 years/cm (2.5±0.09, n=125) and showed non-significant linear relationships with diameter and age (Table 6). Diameter of trees in group 2 ranged from 10−113 cm (41±3.3, n = 60) and ages ranged from 15 to 198 years with a mean annual increment of 2.8±0.09 years/cm. Tree diameter was significantly correlated with age (y =1.663x-14.034, r^2 =0.9436) while, age and growth rate and diameter and growth rate were also significantly correlated (Table 7).

Table 6: DBH, age and growth rates of *P. roxburghii* in three groups derived from Ward's cluster analysis

Groups	Species	Diameter (DBH cm)	Age	Growth rate (year/cm)	Tree samples
1	*P. roxburghii*	57±2.9	115±6.5	2.5±0.09	N=125
	Range	12-155	20-360	0.78-5.2	
2	*P.roxburghii*	41±3.3	54±5.7	2.8±0.09	N=60
	Range	10-113	15-198	1.2-5.3	
3	*P. roxburghii*	45±2.9	69±5.4	2.9±0.13	N=74
	Range	11-116	14-209	1.1-5.5	

Table 7: Regression analysis of DBH, age and growth rates of *P. roxburghii* in three groups derived from cluster analysis.

Groups	Equations (DBH vs Age)	R^2	DBH vs Growth rate	R^2	Age vs Growth rate	R^2
1	y= 20185× + 0.047	0.7597***	y= 0.0035×+	0.0589 ^{Ns}	y= 0.012×+	0.1269
2	y= 1.6631× + − 14.034	0.9436***	y= 0.0117× + 2.256	0.9436***	y= 0.197× + 2.0836	0.4599*
3	y= 1.7458× − 10.074	0.9065***	y= 0.0176× + 1.7288	0.4945*	y= 0.0304× +	0.4398*

Significance levels: *: p <0.05; ***: p <0.001 and Ns: Non-significant

P. roxburghii in group III had diameters ranging from 11−116 cm (45±2.9, n =74) and age from 14−209 years (69±5.4, n =74). Regression analysis showed a significant positive relationship between diameter and age (y =1.7458x - 10.074, r^2 = 0.906). Increment of growth ranged from 1.1−5.5 with an average of 2.9±0.13 years/cm. Similar to group II, the trees in groups III exhibited significant linear relationship between age and diameter (r^2 =0.4945, p <0.005) and diameter and growth rate (r^2 =0.4398, p <0.05) respectively (Table 7).

Discussion

The classification and ordination techniques showed well-defined patterns in vegetation composition and yielded complementary results. Ward's agglomerative clustering procedure partitioned the vegetation into three main groups based on the importance value of tree species. In our study this division was made on the basis of species composition for the entire study area. *P. roxburghii* was the dominant species in terms of its importance value in all stands because it typically grows in pure stands throughout Pakistan, India, Nepal and Bhutan (Sangye 2005; Gupta and Dass 2007; Ghildiyal et al. 2009; Siddiqui et al. 2009). The members of Fagaceae, Sapotaceae and Moraceae are often in association as dominant species on lower elevations (Khan et al. 2011). However, with *P. roxburghii* the members of these families co-occur rarely and whenever associated they are

represented with very low importance values. Species like *Q. baloot*, *Q. incana* and *M. buxifolia* are the common, almost exclusive low altitude evergreen representatives that are found in association with *P. roxburghii* (Badshah et al. 2010; Khan et al. 2010). Singh and Singh (1986) reported that *Q. incana* and *Q. baloot* are widely distributed in the west with higher concentration in the central Himalaya. However, in the present study both species were poorly distributed in few of the forest stands surveyed though frequently distributed at lower elevations in the Hindukush and Himalayan regions (Khan 2012). *Q. dilatata* is typically a west Himalayan species but is poorly represented in Pakistan (Ohsawa et al. 1986; Sheikh and Kumar 2009) and was absent from the entire study sites. Generally, *Quercus* and other broad leaved species occurred with low importance values in the sampled communities.

NMS-ordination of arboreal vegetation (stand ordination) depicted a vegetation continuum that appeared to be a function of altitude and slope as both are correlated with the first ordination axis. Thus topographic gradient was the predominant environmental gradient that controlled the composition of the vegetation as has been reported in other portions of the Hindukush and Himalayan mountains (e.g., Saddiqui et al. 2010; Ahmed et al. 2011; Khan et al. 2013). The first ordination axis also showed positive correlation with soil variables like pH and electrical conductivity. Apparently, the variables related to soil chemistry were associated to topographic characteristics and they probably acted as a secondary gradient (cf. Greig-Smith 1983) which perhaps influences the uptake of nutrients. Such soil patterns appear general for mountain slopes where temperature decreases and rainfall increases with elevation (Allen and Pet 1990).

The density·ha^{-1} of *P. roxburghii* and associated broad leaves species in the present study corresponds with the low altitude species composition recorded for the lesser Himalayan and Hindukush range of Pakistan. The density values in the present study are within the range values that are reported by Ahmed et al. (2006), Wahab et al. (2008), Ahmed et al. (2009), Siddiqui et al. (2009) and Khan et al. (2010) in the low-land dry and moist broad leaved and evergreen conifer forests of the Hindukush and Himalayan ranges. The density of *P. roxburghii* varied significantly between the present study sites. Density was substantially lower at dry sites than at moist sites and *P. roxburghii* occurred more frequently on north facing slopes. Basal area (m^2·ha^{-1}) recorded in this study ranged from 9 to 898.9 m^2·ha^{-1} which is comparatively high for the dominant species and might be attributed to high numbers of individuals in large size classes. However, the basal area values for the associated broad leaved species were low in comparison to the range of 21.33–27.5 m^2·ha^{-1} reported by other workers (Ahmed et al. 2009; Khan et al. 2010; Khan et al. 2011), from undisturbed forests in the lesser Hindukush. The associated broad leaved species contributed less than 10% of the total basal area of all species. The low density and basal area for the associated broad leaved species were due to the low density of sizable trees, perhaps its harvesting for fuel-wood and because of the occurrence of *P. roxburghii* mostly in pure stands.

The reverse J-shaped population structure of *P. roxburghii* in some stands in the study area is in conformity with many other forest stands in lesser Hindukush (Siddiqui et al. 2009; Wahab 2011) and Himalayan forests (Ahmed and Naqvi 2005; Hussain et al. 2010;). The reverse J-shaped pattern for DBH frequency indicated good regeneration potential (Nath et al. 2005). This type of pattern explains indigenous factors and exogenic disturbances (Barker and Kirkpatrick 1994). The negative exponential pattern is characteristic of undisturbed forests (Elouard et al. 1997). However, in the current study *P. roxburghii* was the major contributor in lower size classes, hence showed maximum regeneration potential. The low representation of *P. roxburghii* in both sapling and seedling classes was observed, indicating comparatively low level of regeneration. Generally, the presence of more small-sized tree than large-sized ones is considered as an indication of a regenerating forest (Bhat et al. 2011) but lower number of juveniles is treated as an indicator of the degenerating status of the stand (Condit et al. 1998). In the present study this phenomenon might be attributed to anthropogenic disturbances like illicit cutting and browsing of livestock. Absence of trees from particular size classes was also observed, indicating that mature trees were preferred for cutting or logging for beams and other purposes. Moreover, removal of trees and mortality create gaps and reduced over-crowding resulting quick growth of regenerating species that tend to be straight and tall (Obiri et al. 2002). Such phenomena were observed in *P. roxburghii* stands that lead to the selective harvesting for specific uses from a particular DBH class and non-selective tree cutting for fuel wood have been reported as affecting the forest composition and structure (Saddiqui et al. 2009; Ahmed et al. 2011). The removal of the high number of trees in particular size class suggests that people need them in bulk quantity to meet their various needs. These practices in these forest sites are common due to its low elevation and amidst human habitation lead to rapid deterioration of these economically and ecologically important stands.

The age and growth rate of the species suggested that this species is fast growing and relatively short-lived. In view of its fast growth and longevity, *P. roxburghii* seems a suitable choice for short-term cultural practices to enhance wood production in the lesser Himalaya and Hindukush ranges. These findings are also in agreement with Ahmed et al. (2009) and Ali (2011) who observed this species to be a favorite plant for re and afforestation purposes in the area. The examination of ring-width characteristics suggest that *P. roxburghii* may not be a suitable species in prediction of climatic changes, due to a number of reasons i.e. double ring/missing ring formation, excesses resin and fast growth. In this context, it is extremely difficult to cross-date, though studies have shown the dendroclimatic potential of the species growing at diverse ecological sites in western Himalaya (e.g. Pant and Borgaonkar 1984; Bhattacharyya et al. 1992; Schmidt 1993; Chaudhary et al. 1999; Cook et al. 2003). This difference may be due to the topography and other environmental factors that influence the growth of the species. We also concluded that diameter is a good predictor of age and growth rates in case of *P. roxburghii* as, both the parameters showed strong correlation with diameter. These findings accord well with

those of Ahmed and Sarangzai (1991) who reported that age increases with increasing diameter. It was reported that species from moist temperate areas generally grow faster (Ahmed et al. 2009). However, such a statement is not applicable for all the species. In case of *P. roxburghii* from dry and moist areas, growth is faster than other conifer species because it prefers to grow on moderate to gentle slopes and flat areas mostly on the northern aspect. Therefore, faster growth may be dependent upon the better soil moisture regime of the stands rather than other extrinsic factors or its intrinsic characteristics.

Based on these results, legal categorization and prohibition of extraction by the local communities has little effect on anthropogenic pressure on forests, in deciding extraction pressure are village size, distance, accessibility and approachability. Unless a suitable management package is evolved and implemented, and conservation measures are taken to reduce and control the anthropogenic activities, under the current regime, loss of forest degradation will be continued in northern Pakistan.

References

Ahmed M, Hussain T, Sheikh, AH, Hussain SS, Siddiqui FM. 2006. Phytosociology structure of Himalayan Forest from different climatic zones of Pakistan. *Pakistan Journal of Botany,* **38**(2): 361−382.

Ahmed M, Khan N, Wahab M, Hamza S, Siddiqui F, Nazim K, Khan MU. 2009. Description and structure of *Olea ferruginea* (Royle) forest of Dir Lower District of Pakistan. *Pakistan Journal of Botany,* **41**(6): 2683−2683.

Ahmed M, Naqvi SH. 2005. Tree-ring chronologies of *Picea smithiana* (Wall) Boiss, and its quantitative vegetational description from Himalayan Range of Pakistan. *Pakistan Journal of Botany*, **37**(3): 697−707.

Ahmed M, Nazim K, Siddiqui MF, Wahab M, Khan N, Khan MU, Hussain SS. 2009. Description and structure of Deodar forests from Himalayan range of Pakistan. *Pakistan Journal of Botany*, **42**(5): 3091−3102**.**

Ahmed M, Palmer J, Khan N, Wahab M, Fenwick P, Esper J, Cook E. 2011. The dendroclimatic potential of conifers from northern Pakistan. *Dendrochronologia*, **29**(3): 212−235.

Ahmed M, Sarangzai AM. 1991. Dendrochronological approach to estimate age and growth rates of various species from Himalayan Region of Pakistan. *Pakistan Journal of Botany*, **23**(1): 78−89.

Ahmed M, Shaukat SS, Siddiqui FM. 2011. A multivariate analysis of vegetation of *Cedrus deodara* forests in Hindukush and Himalayan ranges of Pakistan: evaluating the structure and dynamics. *Turkish Journal of Botany*, **35**: 419–438.

Ahmed M, Shaukat SS. 2012. A Textbook of Vegetation Ecology. Karachi: Abrar Sons Publishers, 396 pp.

Ahmed M, Wahab M, Khan N, Saddiqui FM, Khan MU, Hussain ST. 2009. Age and growth rates of some gymnosperms of Pakistan: A dendrochronological approach. *Pakistan Journal of Botany*, **41**(2): 849−860.

Ajaib M, Iqbal A, Khan Z. 2004. Phytosociological studies on the vegetation of Pir Chinasi Hills District Muzaffarabad Azad Jammu & Kashmir. *Proceeding of the National conference Biology,* 2. 227−233 pp.

Ajaib M, Khan Z. 2004. The present position of sub-tropical Pine (Chir) vegetation in the Hills of Saney Baney District Kotli (A.J & K). *In*: *Proceeding of the National conference Biology*, 2. 173−179 pp.

Ali K. 2011. The conservation issues of medicinal plants of the Swat valley, with special reference to the tree flora. *PhD dissertation:* School of Biological Sciences University of Reading UK. pp 1-468.

Allen RB, Pet RK. 1990. Gradient analysis of forests of the Sangre de Cristo Range Colorado. *Canadian Journal of Botany*, **6**: 193−201.

Ashraf I. 1995. Phytosociological studies of *Pir Chinasi* Hills District Muzaffarabad. *M.Sc. Thesis,* University of Azad Jammu & Kashmir Muzaffarabad.

Badshah L, Hussain F, Akhtar N. 2010. Vegetation of subtropical forest of Tabai, South Waziristan, Pakistan. *Frontier of Agriculture in. China*, **4**(2): 232−236.

Baker, Kinkpatrick. 1994. Phyllocaldus asplenifolius: Variability in the population structure of the regeneration niche and dispersion pattern in Tasmanian forest. *Australian Journal of Botany*, **42**: 163−190.

Bhat DM, Hegde GT, Shetti DM, Patgar SG, Hegde GN, Furtado RM, Shastri CM, Bhat PR, Ravindranath NH. 2011. Impact of disturbance on composition, structure and floristics of Tropical Moist forests in Uttara Kannada District, Western Ghats, India. *Ecotropica*, **17**(2): 1−14.

Bhattacharyya A, LaMarche Jr VC, Hughes MK. 1992. Tree-ring chronologies from Nepal. *Tree-Ring Bulletin*, **52**: 59−66.

Bowers NA. 1964. New method of surfacing wood specimen for study. *Tree-Ring Bulletin*. **26**: 2−5.

Brian H. 1991. The Cambridge Encyclopedia of China, Cambridge UP. (2nd edi.)

Carter MR, Gregorich EG. 2008. *Soil Sampling and Methods of Analysis.* Toronto: Canadian Society of Soil Science, p. 1224.

Champion GH, Seth SK, Khattak GM. 1965. *Forest types of Pakistan.* Peshawar: Pakistan Forest Institute, p. 238.

Chaudhary V, Bhattacharyya A, Yadav RR. 1999. Tree-ring studies in the Eastern Himalayan region: Prospects and problems. *IAWA Journal*, **20**: 317–324.

Condit R, Sukumar R, Hubbell SP, Foster RB. 1998. Predicting population trends from size distributions. A direct test in a tropical tree community. The American Naturalist, **152**: 495−509.

Cook ER, Kairiukstis LA. 1990. Methods of dendrochronology: applications in the environmental science. Dordrecht: Kluwer, p. 394.

Cook ER, Krusic PJ, Jones PD. 2003. Dendroclimatic signals in long tree-ring chronologies from the Himalayas of Nepal. *International Journal of Climatology*, **23**: 707−732.

Cottam G, Curtis JT. 1956. The use of distance measures in phytosociological sampling. *Ecology,* **37**: 451−460.

Curtis JT, McIntosh RP. 1950. The interrelation of certain analytic and synthetic phytosociological characters. *Ecology*, **31**: 434−455.

Elouard C, Pascal JP, Pelissier R, Ramesh BR, Houllier F, Durand M, Aravajy S, Moravie MA, Gimaret-Carpentier C. 1997. Monitoring the structure and dynamics of a dense moist evergreen forest in Western Ghats (Kodagu district, Karanataka, India). *Tropical Ecology*, **38**(2): 193−214.

Enright NJ, Miller BP, Akhter R. 2005. Desert vegetation and vegetation-environment relationships in Khirthar National Park, Sindh, Pakistan. *Journal of Arid Environment,* **61**: 397–418.

Fowler HJ, Archer DA. 2006. Conflicting signals of climate change in the upper Indus Basin. *Journal of Climate,* **19**(17): 4276–4293.

Fritts HC, Xiangding W. 1986. A comparison between response function analyses and other regression techniques. *Tree-Ring Bulletin*, **46**: 31–46.

Fritts HC. 1976. Tree-Ring and Climate. New Jersey: Blackburn Press, Caldwell.

Gaur RD. 1982. *Dynamics of vegetation of Garhwal Himalaya*. In: Paliwal, G.S. (ed), *Vegetational Wealth of Himalaya*. New Delhi: Puja publishers, pp.12–22.

Ghildiyal SK, Sharma CM, Gairola S. 2009. Environmental variation in seed and seedling characteristics of Pinus roxburghii Sarg. from Uttarakhand, India. *Applied Ecology and Environmental Research*, **2**: 121–129.

Ghildiyal SK, Sharma CM, Gairola S. 2010. Variation in morphological characters of mycorhizal seedlings of various proruences of *Pinus roxburghii* Sargent. *New York Science Journal*, **3**(2): 1–8.

Greig-Smith P. 1983. *Quantitative plant Ecology*, 3rd ed. Oxford: Blackwell Scientific, p.359.

Gupta B, Dass B. 2007. Composition of herbage in *Pinus roxburghii* Sargent stands: basal area and Importance value index. *Caspian Journal of Environmental Sciences*, **5**(2): 93–98.

Heinrich I. 2004. Dendroclimatology of Toona ciliata. Ph.D dissertation of Australian National University. pp. 1–234.

Huang JG, Zhang QB. 2007. Tree-rings and climate for the last 680 years in Wulan area of northern Qinghai-Tibetan Plateau. *Climate Change*, **80**: 369–377.

Hussain A, Farooq MA, Ahmed M, Akbar M, Zafar MU. 2010. Phytosociology and structure of Central Karakoram National Park (CKNP) of Northern Areas of Pakistan. *World Applied Science Journal*, **9**(12): 1443–1449.

Ives ID, Messerli J. 1989. The Himalaya Dilemma: Reconciling Development and Conservation. Rutledge, London: The United Nation University.

Keen BA. 1931. *The physical properties of soil*. New York: Longman Green and Company, p. 380.

Khan N, Ahmed M, Shaukat SS, Wahab W, Siddiqui FM. 2011. Structure, dynamics, diversity and regeneration potential of *Monotheca buxifolia* (Falc.) A.D. dominated forests District Dir, Pakistan. *Frontier of Agriculture China*, **5**(1): 106–121.

Khan N, Ahmed M, Wahab M, Ajaib M. 2010. Phytosociology, structure and physiochemical analysis of soil in *Quercus baloot* Griff, Forest District Chitral Pakistan. *Pakistan Journal of Botany*, **42**(4): 2429–2441.

Khan N, Shaukat SS, Ahmed M, Saddiqui FM. 2013. Vegetation-environment relationships in the forests of Chitral district Hindukush range of Pakistan. *Journal of Forestry Research*, **24**(2): 205–216.

Khan N. 2012. A community analysis of *Quercus baloot* Griff forest District Dir Upper Pakistan. *African Journal of Plant Sciences*, **6**(1): 21–31.

Kumar M, Rajwar GS, Sharma CM. 2004. Disturbance and dynamics in a sub-tropical forest of Garhwal Himalaya. *Bulletin of the National Institute of Ecology*, **14**: 43–50.

Lv LX, Zhang QB. 2012. Asynchronous recruitment history of *Abies spectabilis* along an altitudinal gradient in the Mt. Everest region. *Journal of Plant Ecology*, **5**(2): 147–156.

Malabadi RB, Nataraja K. 2006. Cryopreservation and plant regeneration via somatic embryogenesis using shoot apical domes of mature *Pinus roxburghii* Sarg. Trees. In vitro cell. *Developmental Biology of Plant,* **42**: 152–259.

Malik NZ, Arshad M, Sarwat NM. 2007. Phytosociological attributes of different plants communities of Pir Chinasi Hills of Azad Jammu and Kashmir. *International Journal of Agriculture & Biology*, **9**(4): 569–574.

Manfred F, Buchroithner, Gamerith H. 1986. On the geology of Trich Mir area, Central Hindukush Pakistan. *Jahrbuch Geolqische Bandesanstalt*, **128**: 367–380.

Manfred FB, Zimmer K. 2000. Generation of a 1:00000 geological map of central Chitral (Hindukush, north Pakistan) by means of GIS-software. *Mitteilungender Österreichischen Geologischen Gesellschaft*, **91**: 11–216.

McCune B, Grace JB. 2002. Analysis of Ecological Communities. Gleneden Beach, Oregon: MjM Software Design, p.304

McCune B, Mefford MJ. 2005. Multivariate Analysis of Ecological Data. PC. ORD Version 5.10 My-M Software, Gleneden Beach, Oregon, U.S.A.

Miehe G, Miehe S, Schlutz F. 2009. Early human impact in the forest ecotone of southern high Asia (Hindu Kush, Himalaya). *Quaternary Research*, **71**: 255–265.

Minchin PR. 1987. An evaluation of the relative robustness of techniques for ecological ordination. *Vegetatio*, **69**: 89–107.

Mueller-Dombois D, Ellenberg H. 1974. *Aims and methods of vegetation Ecology*. New York: John Wiley and sons. Inc., p. 547.

Nafeesa Z, Malik M, Arshad, Sarwat MN. 2007. Phytosociological attributes of different Plant communities of Pir Chinasi Hills of Azad Jammu and Kashmir. *International Journal of Agriculture & Biology*, **9**(4): 565–574.

Nasir E, Ali SI. 1972. *Flora of West Pakistan*. Published under P. L. 480, Research project of U.S.A.D., with coordination of A.R.C. Pakistan.

Nath PC, Arunachalam A, Khan ML, Arunachalam K, Barbhuiya AR. 2005. Vegetation analysis and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, Northeast India. *Biodiversity and Conservation*, **14**: 2109–2136.

Obiri J, Lawes M, Mukolwe M. 2002. The dynamics and sustainable use of the coastal Pondoland forests of the Eastern Cape Province, South Africa. *Forest Ecology and Management*, **166**: 131–148.

Ogden J, Ahmed M. 1989. Climate response function analysis of Kauri (Agathis australis) tree-ring chronologies in northern New Zealand. *Journal of the Royal Society of New Zealand*, **19**: 205–221.

Ogden J, Powell JA. 1979. A quantitative description of the forest composition on an altitudinal gradient in Mount Field National Park, Tasmania and a discussion of its history and dynamics. *Australian Journal of Ecology*, **4**: 293–325.

Ogden J. 1980. Dendrochronology and dendroecology: In introduction. *New Zealand Journal of Ecology*, **3**: 154–156.

Ogden J. 1981. Dendrochronological studies and the determination of tree ages in the Australian tropics. *Journal of Biogeography*, **8**: 405–420.

Ohsawa M, Shakya PR, Numata M. 1986. Distribution and succession of west Himalayan forest types in the eastern part of Nepal Himalaya. *Mountain Research and Development*, **6**: 143–147.

Orloci L, Kenkel NC. 1985. Introduction to data analysis in ecology and systematic. Springer-Verlog. Berlin.

Pant GB, Borgaonkar HP. 1984. Growth rate of Chir pines (*Pinus roxburghii*) trees in Kumaon area in relationship to regional climatology. *Himalayan Research and Development*, **3**: 1–5.

Pilcher JR. 1990. Sample preparation, cross-dating and measurement. *In*: Cook, E.R and L.A. Kairiukstis (eds.), *Method in Dendrochronology*. Dordrecht, Netherland: International Institute for Applied System Analysis, pp.40–51.

Ravindra B, Malabadi, Nataraja K. 2007. Plant regeneration via somatic embryogenesis using secondary needles of mature trees of *Pinus roxburghii* Sarg. *International Journal of Botany*, **3**(1): 40–47.

Roza V. 2004. A dendroecological reconstruction of age structure and past management in old-growth pollarded parkland in northern Spain. *Forest Ecology and Management*, **195**: 205–219.

Russell FL, Fowler NL. 1999. Rarity of Oak saplings in savannahs and woodland of eastern Edwards Plateau, Texas. *Southwest Nat,* **44**: 31–41.

Ryniker KA, Bush JK, Auken OWV. 2006. Structure of *Quercus gambelii* communities in Lincoln National Forest, New Mexico, USA. *Forest Ecology and Management*, **233**: 69−77.

Saddozai AQK. 1995. Revised Working Plan for Dir Kohistan Forests of Dir Forest Division. pp.1−136.

Sangye M. 2005. The Impact of Fire Frequency on the Regeneration of *Pinus roxburghii* in Eastern Bhutan. Dissertation of Master of Science in Mountain Forestry University of Natural Resources and Applied Life Sciences, (BOKU), Vienna, pp.1−77.

Schmidt B. 1993. Dendrochronological research in south Mustang. *In*: Ancient Nepal, edited by K.M Shrestha, T, Mishra and R. Pradhan*, Journal of the Dep. of Archeology*. HMG, Ministry of Education, Nepal.

Sethi HN. 2001. *The Environment of Pakistan*. London UK: Peak Publishing (ISBN 1-901458-490), p.182.

Shaheen H, Qureshi RA, Shinwari ZK. 2011. Structural diversity, vegetation dynamics and anthropogenic impact on lesser Himalayan sub-tropical forests of Bagh District, Kashmir. *Pakistan Journal of Botany*, **43**(4): 1861−1866.

Shaukat SS. 1989. A technique for species weighting and its utility in data reduction and minimization of miss classification. *Coenoses*, **4**: 163−168.

Sheikh MA, Kumar M. 2009. Nutrient status and economic analysis of soil in oak and pine forests in Garhwal Himalaya. *Journal of American Science*, **6**(2): 117−122.

Siddiqui FM, Ahmed M, Shaukat SS, Khan N. 2010. Advance multivariate techniques to investigate vegetation-environmental complex of pine forests of moist area of Pakistan. *Pakistan Journal of Botany*, **42**: 267−293.

Siddiqui MF, Ahmed M, Wahab M, Khan N. 2009. Phytosociology and structure of *Pinus roxburghii* Sargent (Chir Pine) in lesser Himalayan and Hindukush range of Pakistan. *Pakistan Journal of Botany,* **41**(5): 2357−2369.

Singh JS. 1985. Environmental Regeneration in Himalaya: Concepts and Strategies. CHEA and Gyanodaya Prakashan, Naintital.

Singh R. 1976. Structure and net community production of the herbaceous vegetation in the sand dunes regions around Pilani, Rajasthan. Ph.D. Thesis, BITS, Pilani, Rajasthan. p. 460.

Singh SP, Singh JS. 1986. Structure and function of the central Himalayan Oak forest. *Proceedings of Indian National Science Academy*, **96**: 159−189.

Sparks DL. 1996. Methods of soil analysis: Chemical methods, Part 3: Issue 5 of Soil Science Society of America book series. p. 1390.

Speer JH. 2010. *Fundamentals of Tree Ring Research*. The University of Arizona Press, USA. p. 333.

Strokes MA, Smiley TL. 1968. *An introduction to tree-ring dating.* Chicago: University of Chicago Press.

Timilsina N, Ross MS, Heinen JT. 2007. A community analysis of Sal (*Shorea robusta*) forests in the western Terai Nepal. *Forest Ecology and Management*, **241**(1-3): 223–234.

Wahab M, Ahmed M, Khan N. 2008. Phytosociology and dynamics of some pine forests of Afghanistan. *Pakistan Journal of Botany*, **40**(3): 1071−1079.

Wahab M. 2011. Population dynamics and dendrochronological potential of pine tree species of District Dir Pakistan. Ph.D dissertation. Department of Botany Federal Urdu University Karachi Pakistan.